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NUCLEAR SPIN RELAXATION IN TWO-DIMENSIONAL HEISENBERG ANTIFERROMAGNET S=1/2 WITH SKYRMIONS

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The nuclear spin relaxation rate $1/T_1$ is calculated for a two-dimensional quantum Heisenberg antiferromagnet $S=1/2$ with thermally excited skyrmions at temperatures $T \leq J$, where J is the nearest-neighbor exchange constant. It is found that $1/T_1$ first exponentially decreases with increasing temperature, passes a minimum at $T_{min} = 0.67J$ and then linearly increases before approaching its high-temperature limit. A comparison with calculations for a nonlinear sigma-model without skyrmions and experimental results is given. © 1998 Elsevier Science Ltd. All rights reserved

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1. INTRODUCTION

It is well known that the two-dimensional (2D) ferromagnet and antiferromagnet support topologically nontrivial spin textures called skyrmions representing domain-loops within which the staggered magnetizations are reversed [1]. A renewed interest to these systems is stimulated by the search of alternative approaches in investigations of a role of 2D antiferromagnetic spin correlations in an unusual behavior of the cuprate superconductors and their parent compounds [2, 3]. In a recent paper a study of magnetic properties of 2D quantum Heisenberg antiferromagnet (QHAF) with $S = 1/2$ on a square lattice based on a picture of thermally excited skyrmions and antiskyrmions has been reported [4]. The local staggered magnetizations, energy spectrum of spin excitations above the skyrmion's background, the skyrmion averaged radius and renormalized by quantum fluctuations energy were calculated by the Green functions method. It has been found that the temperature dependence of the skyrmion (antiskyrmion) radius mapps very well the corresponding results for the spin correlation length of 2D QHAF calculated by means of renormalization group analysis of a non-linear σ-model [5, 6] and using the $1/N$-expansion method for the N-component order parameter [7] both in the absence of any skyrmions. To make possible a comparative analysis of these approaches and to reveal peculiarities of properties of 2D QHAF with skyrmions, it is desirable to calculate their static and dynamical characteristics which could be measured by well developed experimental methods and easily compared.

In this communication we report our study of the dynamical spin susceptibility and nuclear spin relaxation rate $1/T_1$ in the temperature region $T \leq J$, where J is the nearest-neighbor exchange coupling. We have found that $1/T_1$ exponentially diverges at low temperatures $T \ll J$ and linearly increases with temperature for $T \sim J$, having a minimum before approaching its high-temperature limit. It is remarkable that this behavior of $1/T_1$ is almost identical at low temperatures with results of Chakravarty and Orbach (CO) [8] based on the renormalization group approach [5, 6] (see, also, [9]) and with results of Chubukov et. al. [7] obtained for 2D QHAF in the absence of skyrmions. Moreover, in the CO theory the minimum was qualitatively predicted. At the same time our $1/T_1$ at high temperatures differs sufficiently from [7], where an independence of the relaxation rate on temperature for $T \sim J$ was obtained.